

T-992: Radiation-Hard Sensors at FTBF for the SLHC

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ALL EXPERIMENTERS' MEETING

January 23rd, 2012

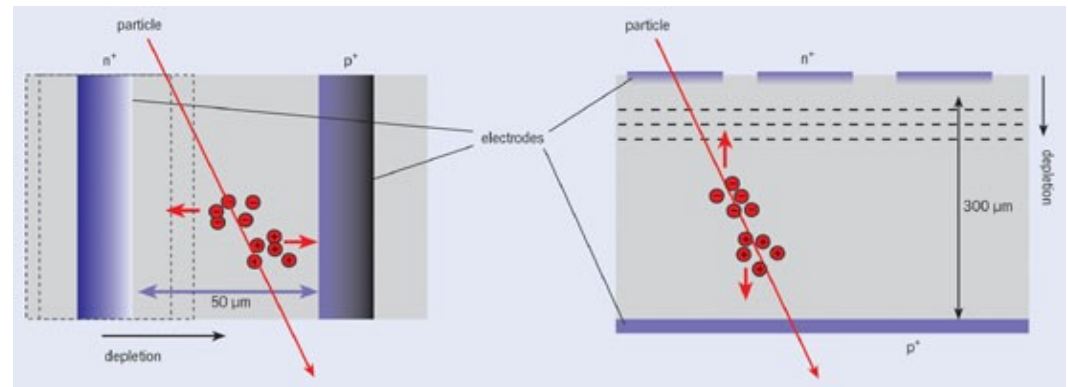
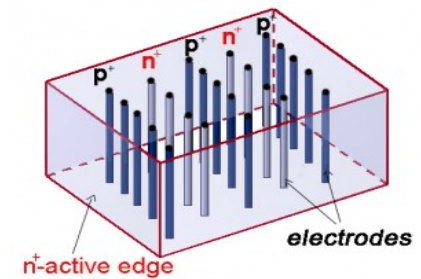
Test Beam Goal

- test the candidate pixel sensors for the SLHC Pixel upgrade before and after irradiation to compare the performances to understand if we have a technology capable of withstanding the enormous fluences
- efforts have been focused on the two most promising sensor types:
 - ◆ **3D Silicon sensors**
 - ◆ **Diamond sensors**
- this talk will present the preliminary analysis and results from last week's run

3D Silicon & Diamond Sensors

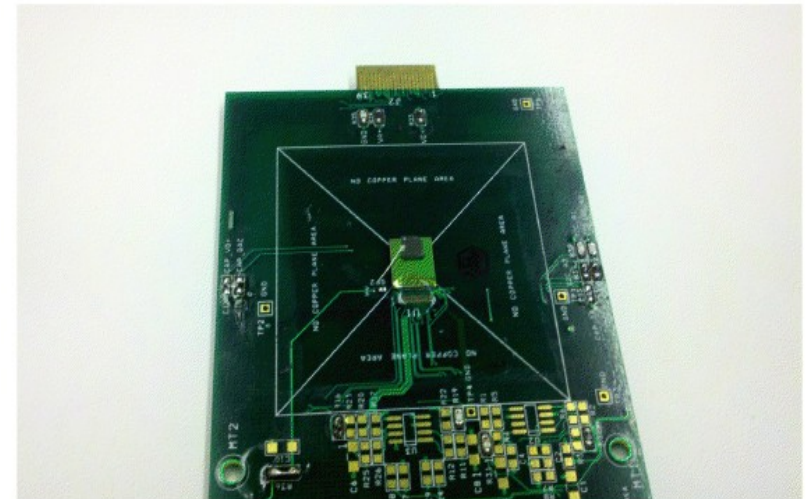
3D Sensors

- first proposed by Sherwood Parker of the University of Hawaii and colleagues in 1995
- p^+ and n^+ electrodes are arrays of columns that penetrate through the silicon bulk
- Lateral depletion: good for rad-hard
 - ◆ shorter collection path
 - ◆ lower full-depletion voltage
 - ◆ less carrier trapping
 - ◆ faster charge collection



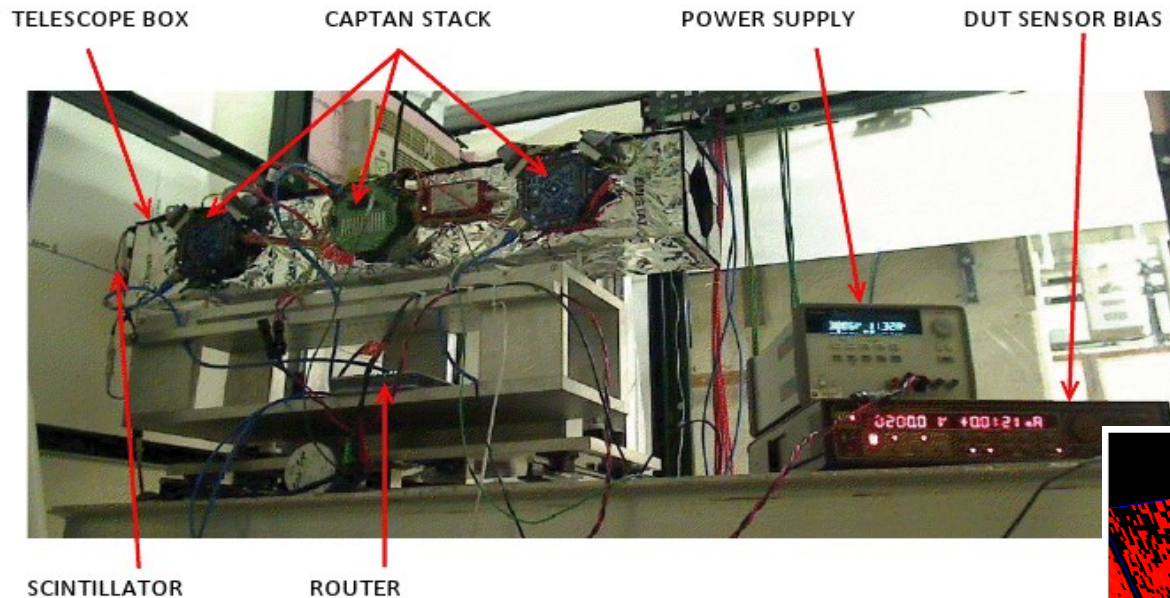
Diamond sensors - intrinsically rad-hard

- high bandgap and high displacement energy
- fast charge collection
- absence of thermally generated leakage current

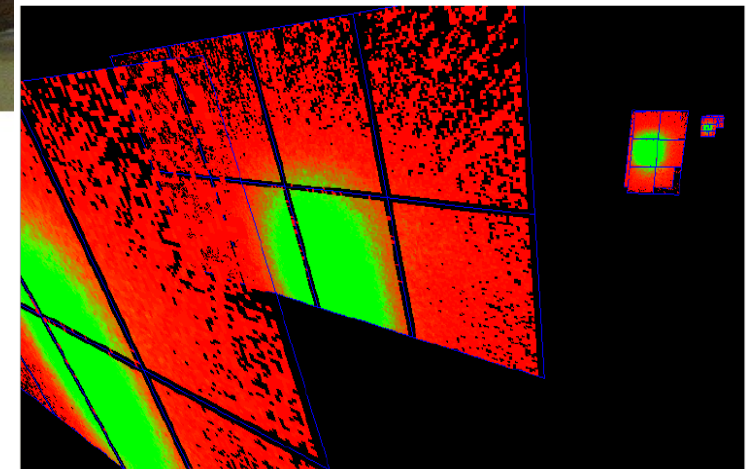


Setup

- Telescope with 8 silicon planar pixel sensors (4 upstream and 4 downstream) with 2 Detectors Under Test (DUTs) in the middle
- The projected track resolution on the DUT is 6 - 10 μm
- Data acquisition with CAPTAN system



Our software allows us to check immediately the data quality!



Collaboration

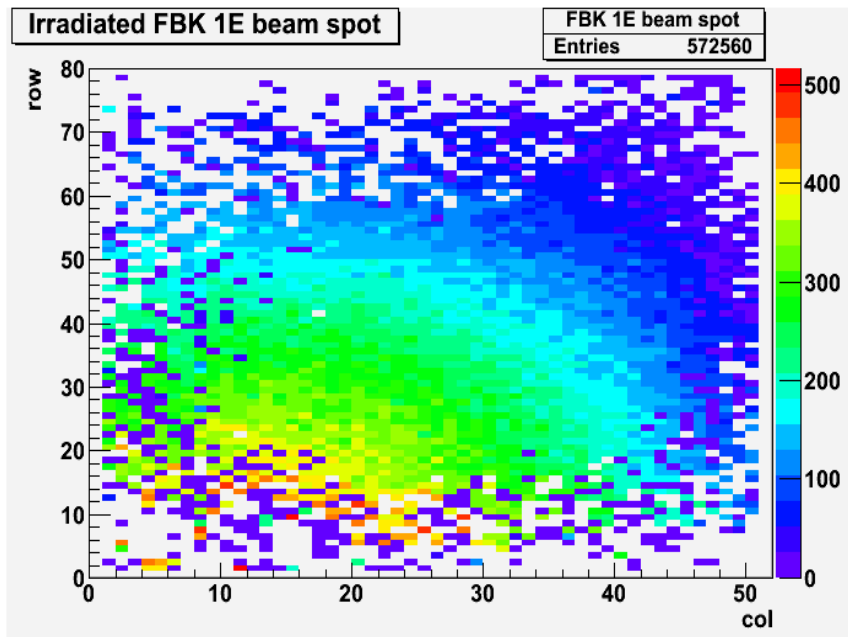
Many different institutions and collaborators for the CMS pixel upgrade:

- Femilab
S. Kwan, A. Prosser, L. Uplegger, R. Rivera, J. Andresen, J. Chramowicz, P. Tan, C. Lei
- Purdue
E. Alagoz, O. Koybasi, G. Bolla, D. Bortoletto, M. Bubna, A. Krzywda
- Colorado
M. Dinardo, S. Wagner, J. Cumalat
- Texas A&M
I. Osipenkov
- Milano
L. Moroni, D. Menasce, S. Terzo, J. Ngadiuba
- Torino
M. Obertino, A. Solano
- Mississippi
L. Perera
- Buffalo
A. Kumar, R. Brosius
- IHPC Strasbourg
J. M. Brom

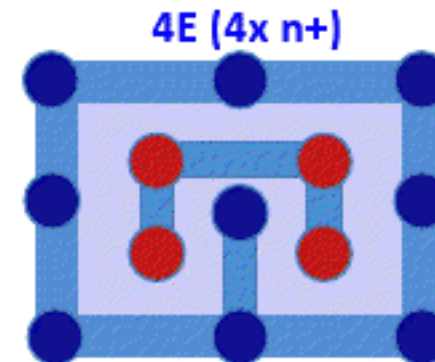
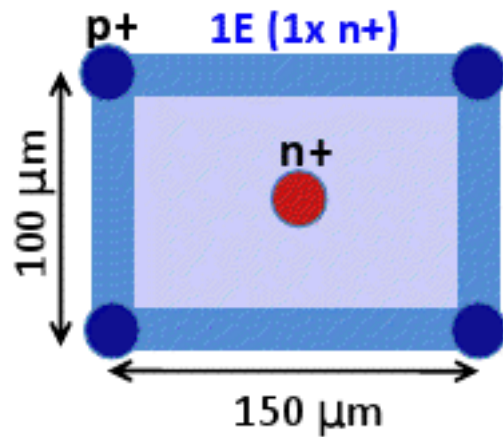
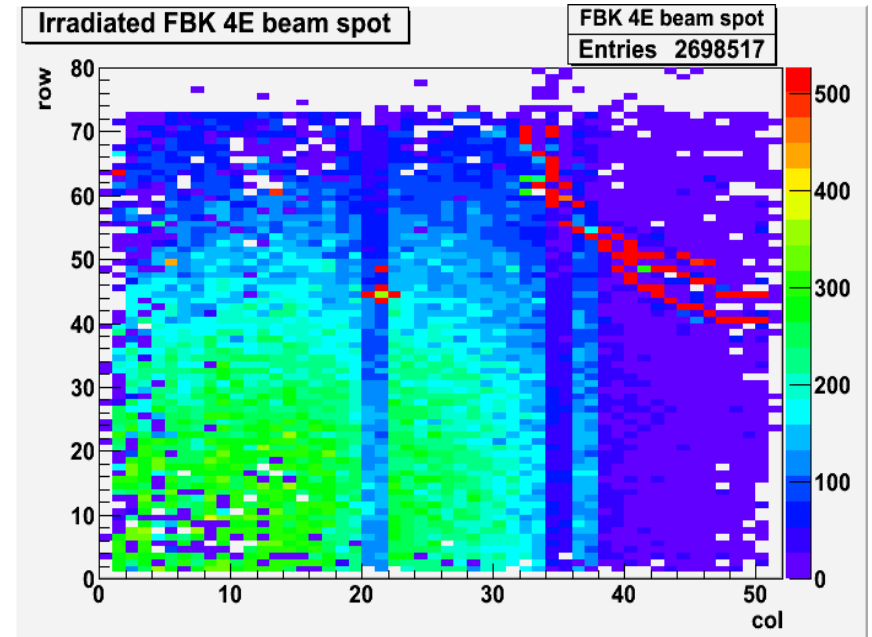
1×10^{14} n-eq/cm² irradiated 3Ds

Beam spots

3D 1E sensor

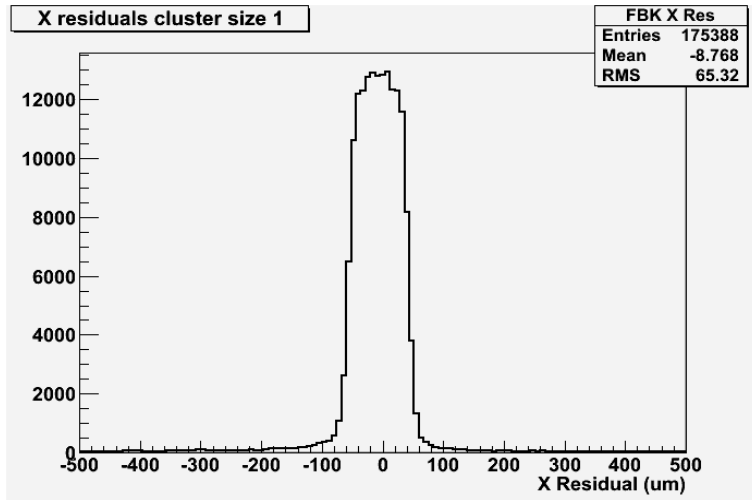


3D 4E sensor

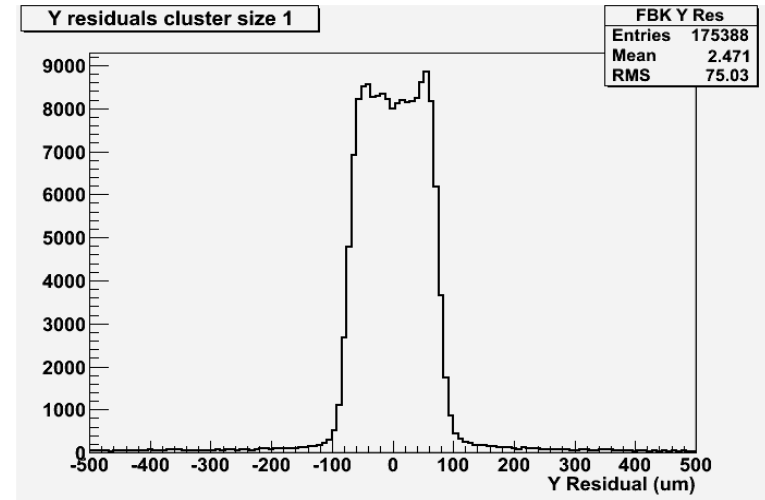


Irradiated 3Ds resolution

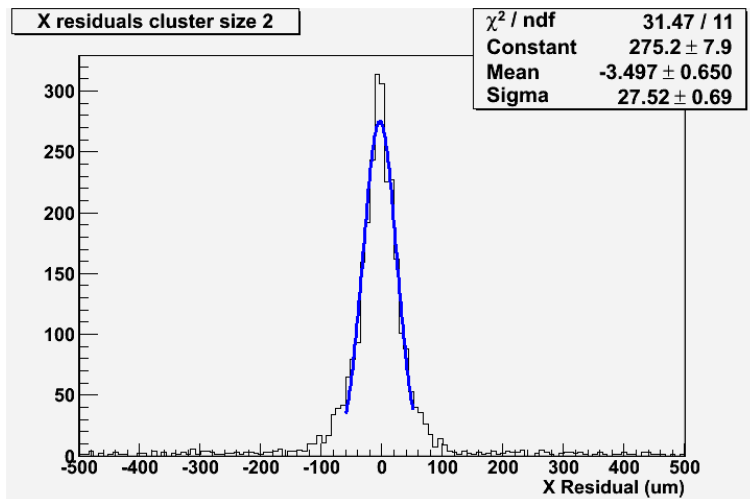
X Residuals Cluster Size 1
 $\sigma = 31.18 \mu\text{m}$



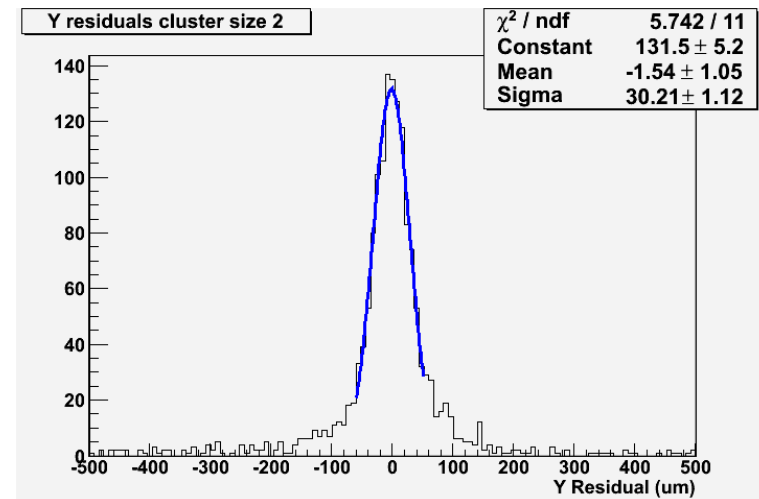
Y Residuals Cluster Size 1
 $\sigma = 46.46 \mu\text{m}$



X Residuals Cluster Size 2
 $\sigma = 27.52 \mu\text{m}$

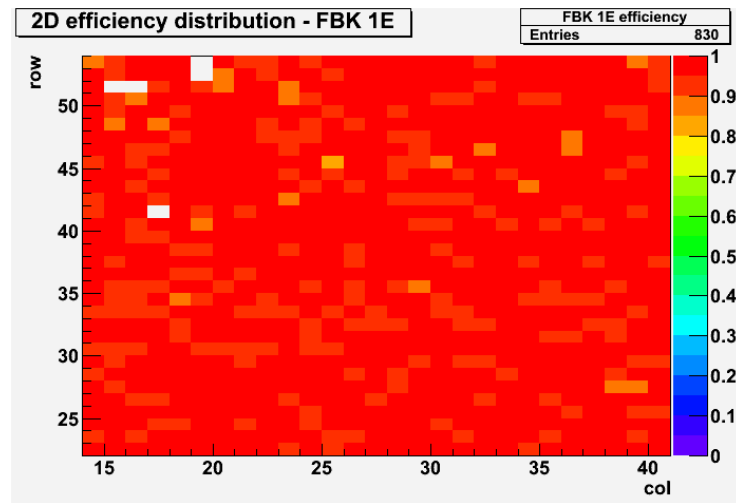


Y Residuals Cluster Size 2
 $\sigma = 30.21 \mu\text{m}$



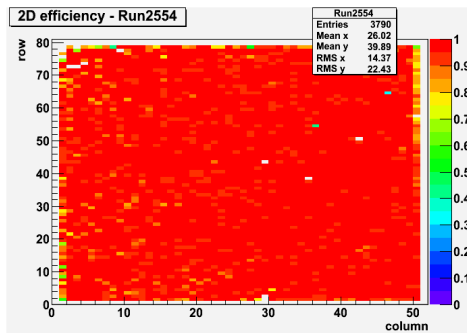
Irradiated 3D 1E efficiency

Efficiency distribution across a part of the detector



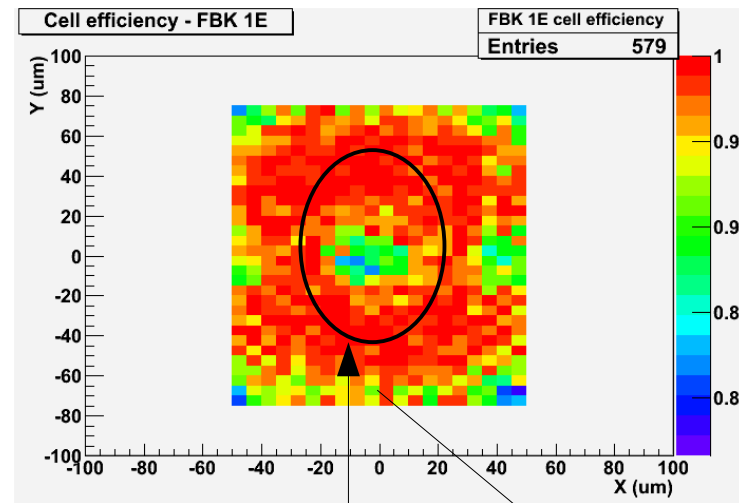
Efficiency ~ 96.6%

Result very similar to not-irradiated 3D detector presented at the November 14th AEM meeting

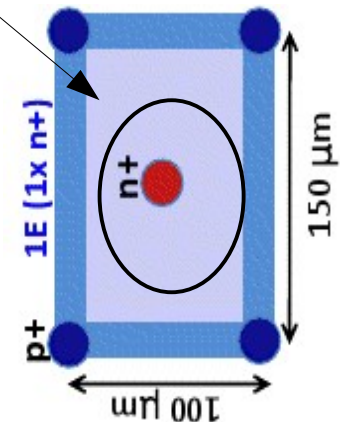


Not-irradiated 3D detector
Efficiency ~ 97.6%

Efficiency distribution across the single pixel cell

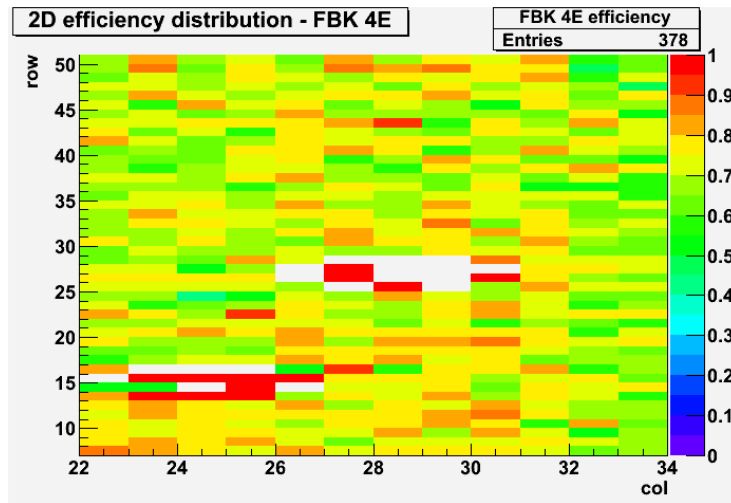


Inefficiency mainly due to particles passing through the p+ and n+ electrodes!



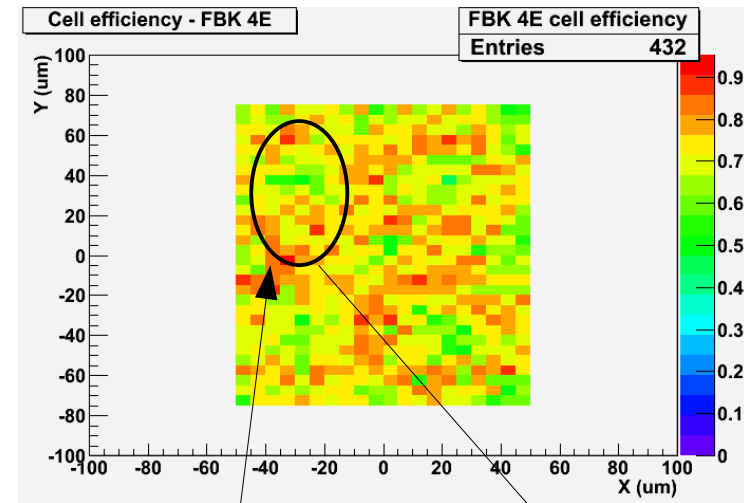
Irradiated 3D 4E efficiency

Efficiency distribution across a part of the detector

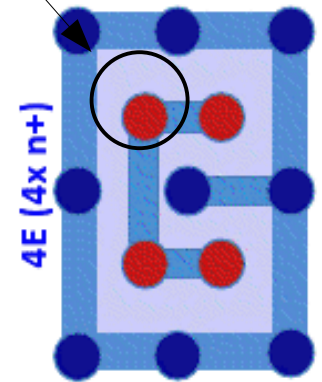


Efficiency ~ 71.9%

Efficiency distribution the single pixel cell



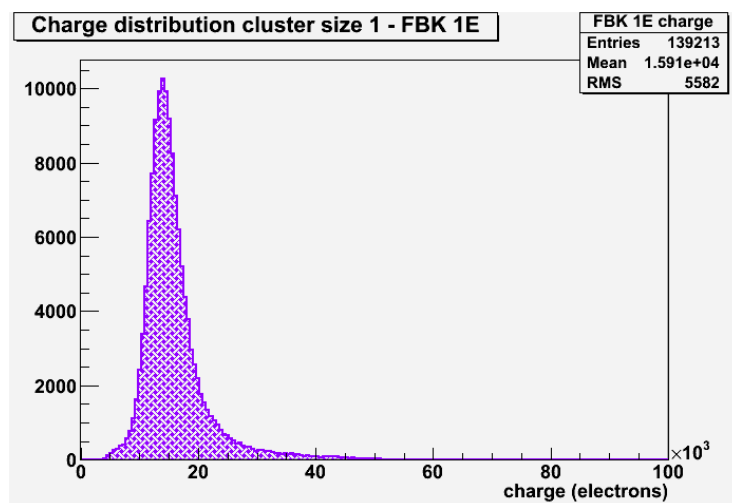
Inefficiency mainly due to particles passing through the p+ and n+ electrodes!



4E 3D detectors never worked as good as 1E or 2E 3D design!

Irradiated 3Ds charge

Charge distribution 3D 1E

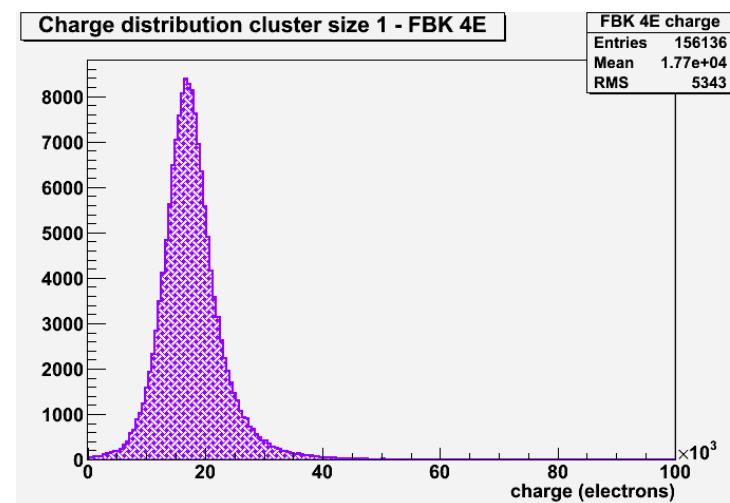


MPV ~ 14.3k electrons

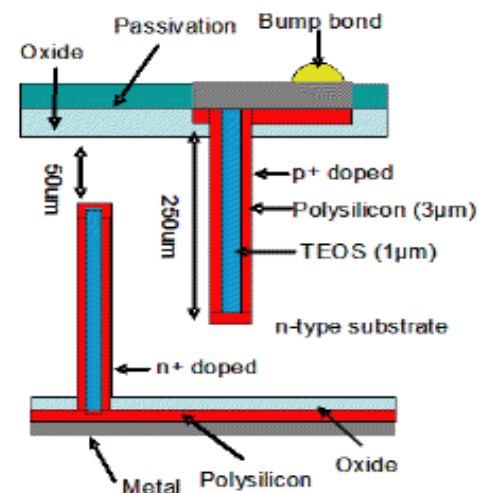


In agreement with the expected charge released in a 200/235 μm thick silicon

Charge distribution 3D 4E



MPV ~ 17k electrons

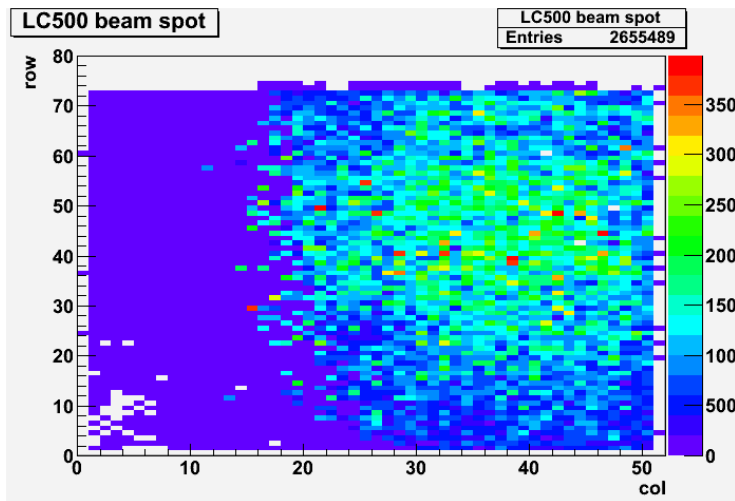


Diamond sensors

Beam spots

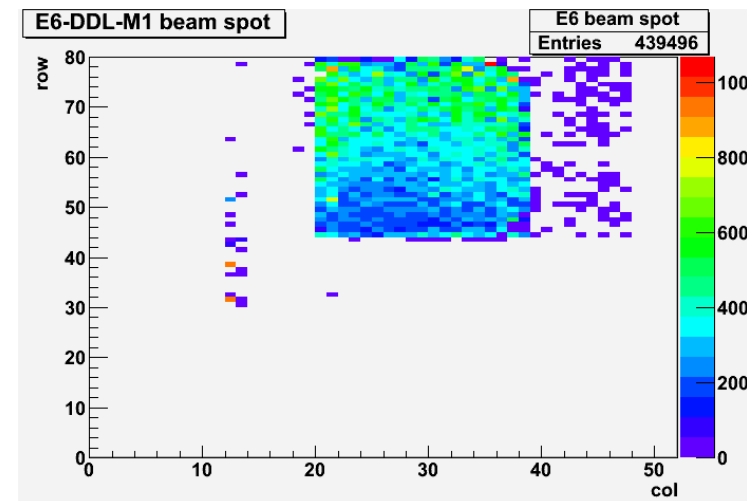
LC500

non irradiated 500 μ m thick
polycrystal diamond sensor



E6-DDL-M1

500 μ m thick monocrystal diamond sensor
irradiated to 3.6×10^{14} n-eq/cm²

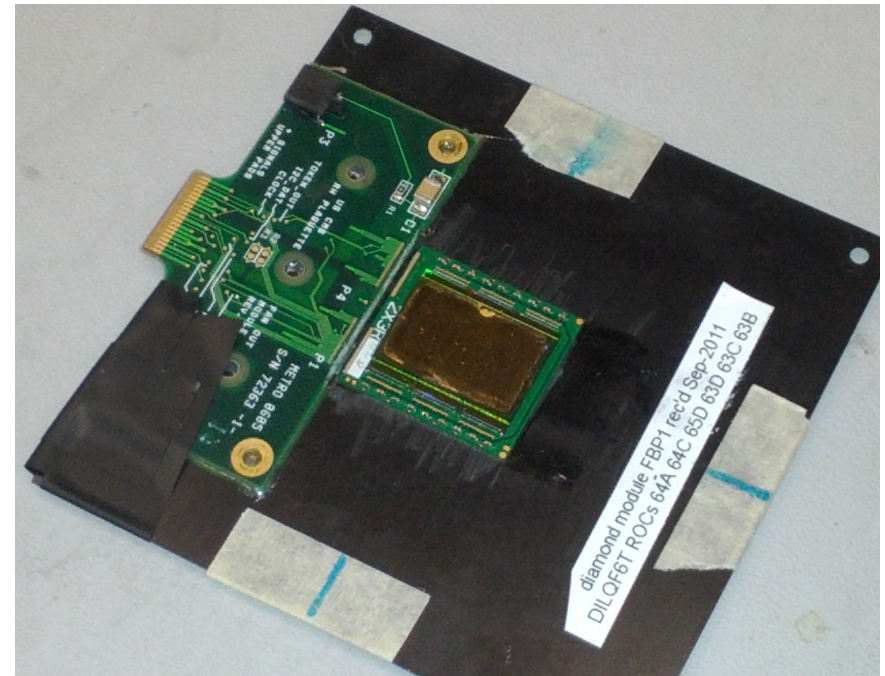
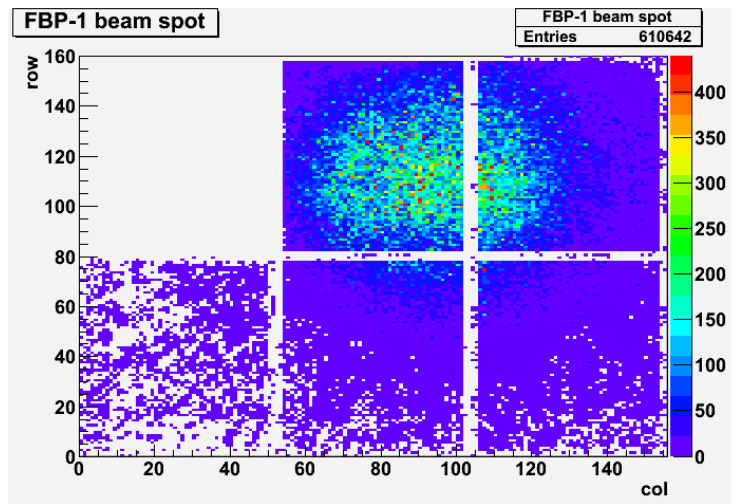


Diamond sensors

Beam spots

FBP-1

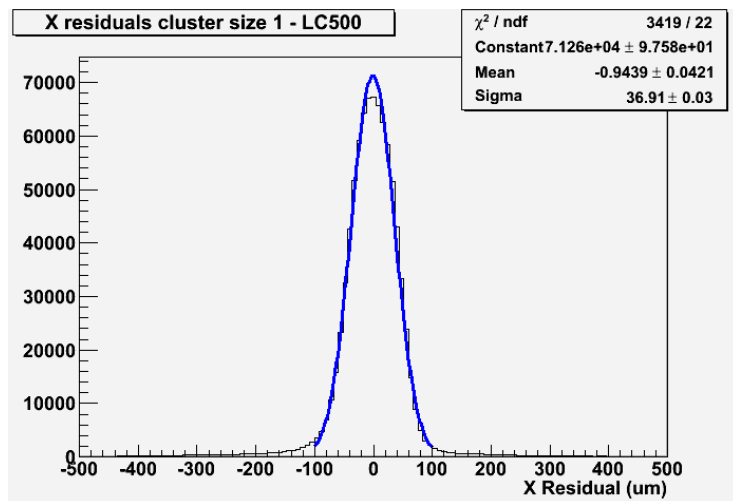
non irradiated $750\mu\text{m}$ thick
2x3 polycrystal diamond sensors



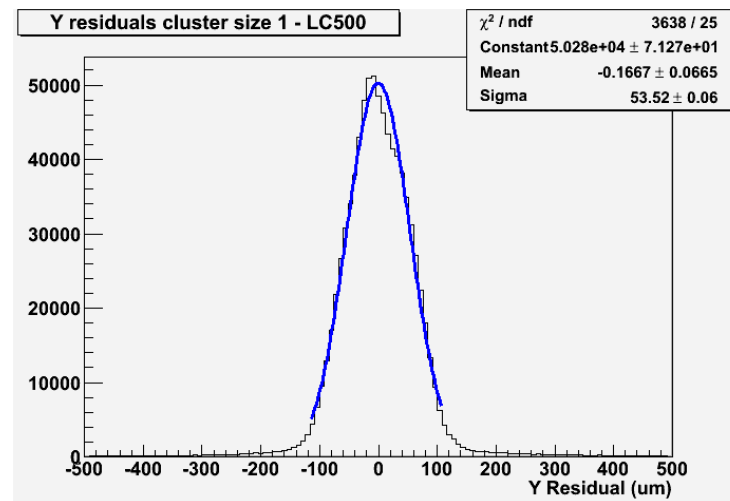
First time we acquired data with a module sized diamond detector!

LC500 resolution

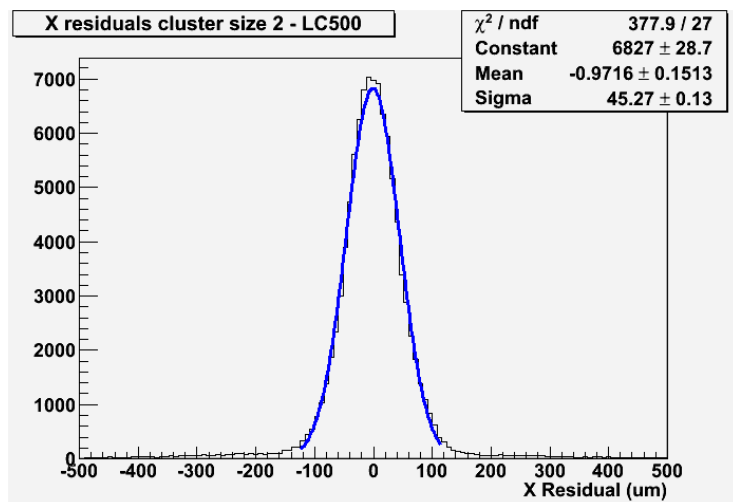
X Residuals Cluster Size 1
 $\sigma = 36.91 \mu\text{m}$



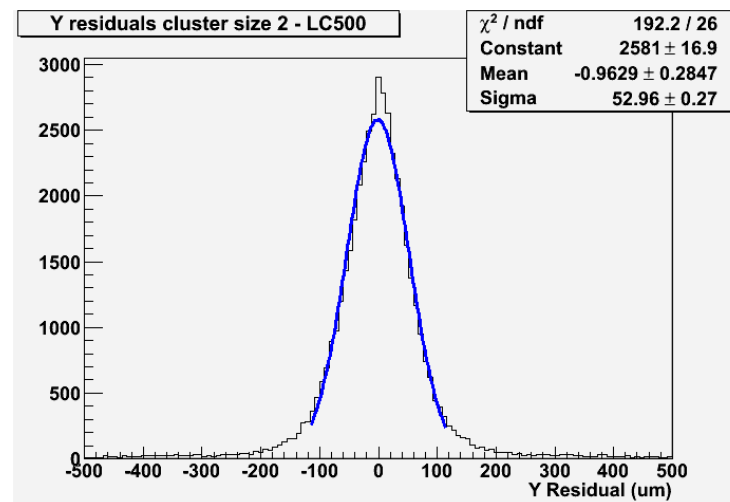
Y Residuals Cluster Size 1
 $\sigma = 53.52 \mu\text{m}$



X Residuals Cluster Size 2
 $\sigma = 45.27 \mu\text{m}$

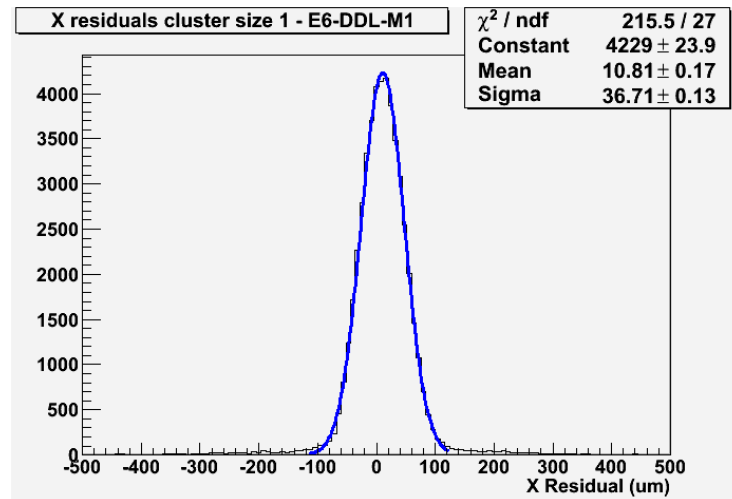


Y Residuals Cluster Size 2
 $\sigma = 52.96 \mu\text{m}$

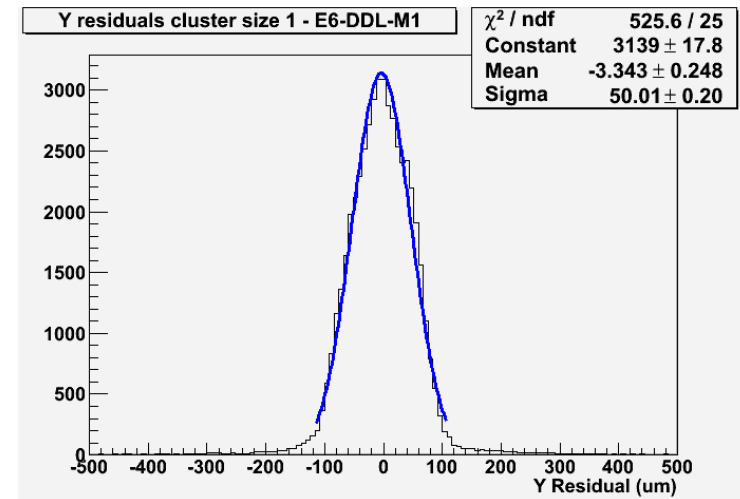


Irradiated Diamond resolution

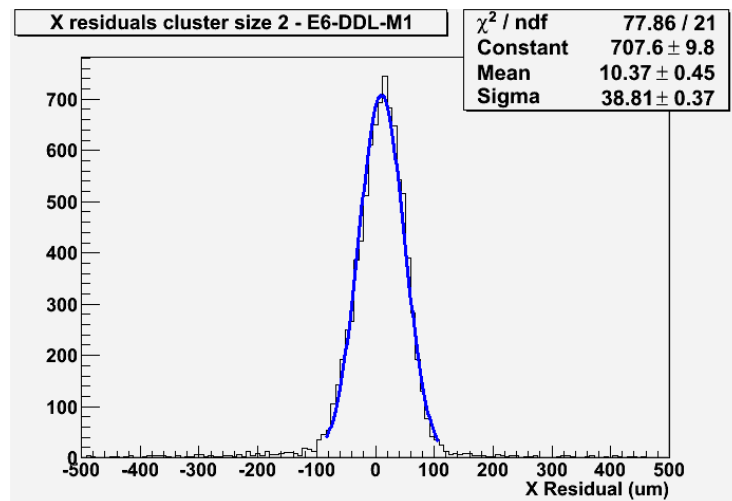
X Residuals Cluster Size 1
 $\sigma = 36.71 \mu\text{m}$



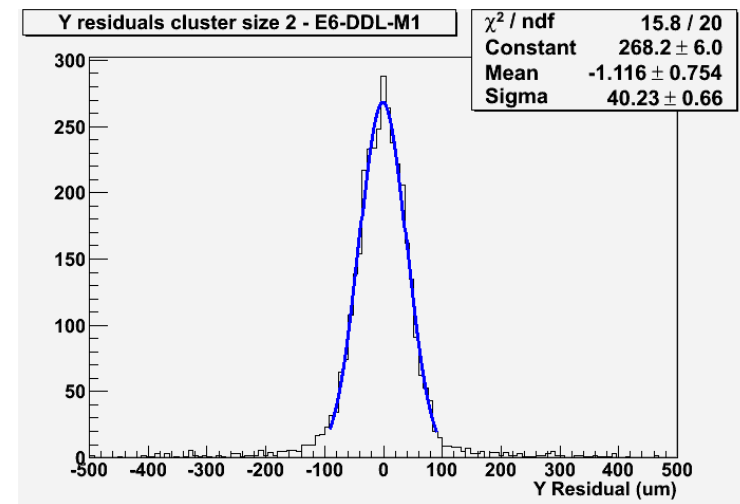
Y Residuals Cluster Size 1
 $\sigma = 50.01 \mu\text{m}$



X Residuals Cluster Size 2
 $\sigma = 38.81 \mu\text{m}$

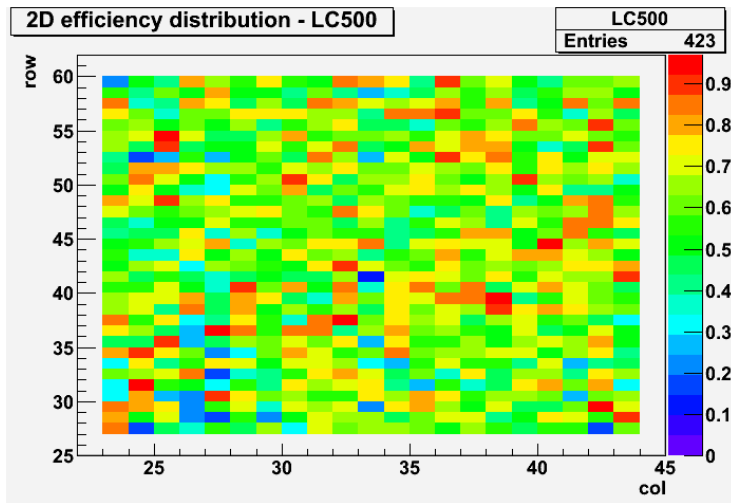


Y Residuals Cluster Size 2
 $\sigma = 40.23 \mu\text{m}$

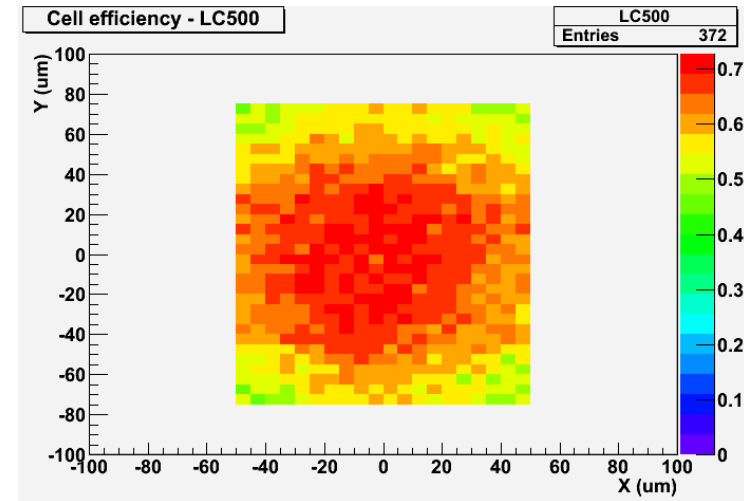


LC500 efficiency

Efficiency distribution across a part of the detector



Efficiency distribution the single pixel cell



Due to the high bandgap the charge released by particles is low



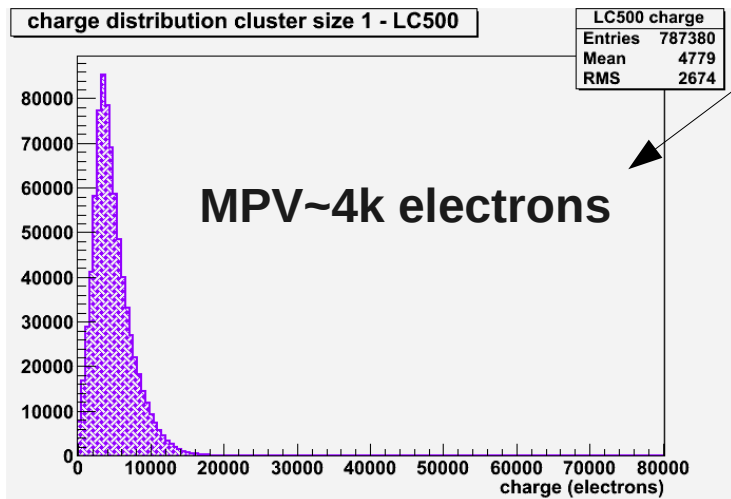
Inefficiency mainly due to events that don't pass the threshold

Efficiency ~ 62.3%

Unable to operate the detector with a lower threshold

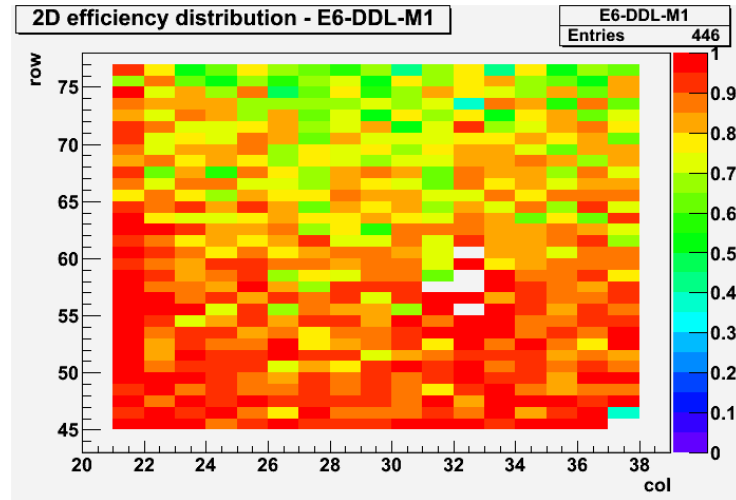
It's important to modify the future electronics to make this possible

charge distribution

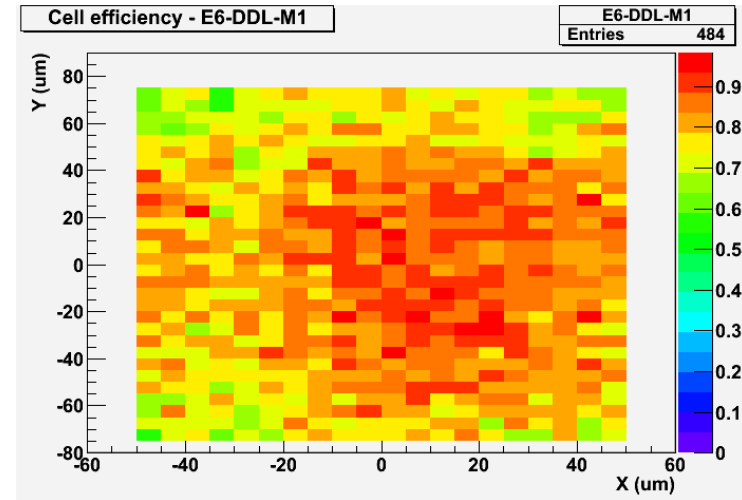


Irradiated Diamond efficiency

Efficiency distribution across a part of the detector



Efficiency distribution the single pixel cell



Efficiency ~ 80.4%

- The longer Charge Collection Distance of the monocrystal relative to the polycrystal makes this detector more efficient even after irradiation
- Charge calibration has not been done because the detector was damaged when we tried to operate it at -700V bias voltage

Conclusions

- We achieved our goal of thoroughly testing 6 sensors in a compact one week schedule – many thanks to the Test Beam Facility!
- 2 types of detectors tested, 3D Silicon and Diamond:
 - ◆ irradiated 1E and 4E 3D Silicon
 - ◆ irradiated monocrystal and non-irradiated polycrystal Diamond, single chip and multichip
- these are the main candidates to replace existing planar technology Si sensors in LHC phase 2 run and for the first time we tested a 2x3 diamond sensor
- the results of this preliminary (a few days) analysis already show the main characteristics/performance of the detectors and highlight sensor issues that still need to be fixed/understood
- for Diamond the need for a new electronics with much lower threshold is clearly emerging and furthermore, charge-sharing in Diamond must be better studied and understood
- 3D Silicon presents an efficiency which is intrinsically limited by the cross section of the column implants
- next we have to refine the analysis and extend it to the full data sample to investigate the still outstanding issues in order to finally better tune the plan for the next test beam campaign in late March